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Title: Switching modulator

Background of the invention

In an RFID system (Radio Frequency IDentification), identification labels are read out by a reader unit, also referred to as interrogator or reader. There is a large variety of applications for these systems, such as access control, animal identification and livestock management systems, identification of goods, industrial automation, etc.

Traditionally, a reader unit consists of a transmitter circuit which generates a high-frequency signal of some power and with which, by means of an antenna coil, a magnetic field is generated. This magnetic field in turn induces a voltage in a coil of a label present in the field. With that voltage, an electronic circuit is supplied that generates a code representing the number that is stored in the memory of the circuit. One or more properties of the resonance circuit of which the above-mentioned coil is a part, is modulated with the code signal. With that, the secondary magnetic field of the coil is also modulated, and this signal is received back in the antenna coil of the reader unit. A receiver circuit, also connected with the antenna coil, selects this label signal out, amplifies and decodes it, thereby reading out the number stored in the label.

In the oldest RFID systems, the number was unchangeably stored during the production of the label. In later systems, it became possible to modify this number, or to store entirely different data in the label. This makes it necessary for the signal transmitted by the reader unit not only to have as a task to provide the label with energy, but also to work as carrier wave for transporting data from the reader unit to the label. In view of the

requirement to limit the complexity of the circuit in the label, amplitude modulation (AM, ASK, OOK) is a preferred modulation form.

In the newest RFID systems, the signal transmitted by the reader unit has been given a further, third function, viz. that of control signal for the purpose of the communication protocol. This involves the so-called Reader Talk First systems. In the previous systems (Tag Talk First), a label starts to transmit its code signal as soon as sufficient energy is being drawn from the magnetic field. As a consequence of this, in the case where several labels are located in the field simultaneously, these labels (may) start to transmit simultaneously as well, so that the reception in the receiver of the reader unit is disturbed. In many applications, however, it is necessary that a large number of labels may be located in the interrogation field simultaneously. This problem is solved by means of an anti-collision protocol in combination with the Reader Talk First principle. A label does not start to transmit its data signal until the reader unit has given a command to that effect. If several labels are located in the field, these labels are allocated to time slots, temporarily switched off, or otherwise controlled in accordance with the respective protocol. There are many different anti-collision protocols known.

Mentioned by way of example here are the systems that meet the standard for vicinity person cards according to ISO 15693. The carrier frequency of the interrogation signal is 13.56 MHz. The interrogation signal is modulated by briefly interrupting the carrier (100% modulation) or inducing a dip in the amplitude (modulation depth about 20%). The duration of these interruptions or dips is 9.5 or19 μs. The data is encoded in the position of the modulations. Fig. 1 illustrates this process.

Amplitude modulation is generated, for instance, by varying the supply voltage of one or more amplifier stages. For an optimum power efficiency,

this can be carried out best on the last amplifier stage, which delivers the transmission energy to the antenna (output stage).

In these RFID systems, the interrogator continuously transmits a carrier, which carrier generates the supply voltage in the label. By means of amplitude modulation of this carrier, data is sent to the label, and subsequently the label is triggered to transmit a return signal.
In the earlier-mentioned standard, it can be found that the data communication from the label to the reader unit proceeds by means of modulation of a subcarrier. This subcarrier in turn modulates the resonance circuit in the label. The subcarrier frequencies in the case of ISO standard 15693 are 424 and 484 kHz. These subcarriers give rise to sidebands at the frequencies 13.56 MHz ± 424 kHz and 13.56 MHz ± 484 kHz.
The receiver section of the reader unit thus receives in either of the two pass bands, 13.56 MHz ± (400 - 500) kHz, or both.
If this interrogation signal is contaminated with noise which has been sidebands, this noise is also received in the receiver. As a consequence, the label signals to be received may be masked by this transmitter noise.

modulation, phase modulation, or a combination of the two possibilities. This noise is then constantly present, also in the receiving periods. To prevent this parasitic modulation of noise, these supply voltages need to be filtered properly, *inter alia* by means of parallel capacitors having high capacitance values. This requirement, however, is in conflict with the requirement of being able to vary the supply voltage fast for amplitude modulation of the interrogation signal.

Summary of the invention

The object of the invention is to provide a solution to the above-indicated problem.

A solution in the context of the invention is given by utilizing at least two voltage sources and switching the supply of the transmitter amplifier between at least these two voltage sources.

Brief description of the drawings

These and other objects and advantageous aspects of the invention will be described on the basis of an embodiment, with reference to the following drawings.

Figure 1 illustrates a modulation process according to the prior art;
Figure 2 shows a modulation circuit;
Figures 3 and 4 show graphs of signal forms;
Figures 5, 6-9 show amplitude modulation forms;
Figures 10 and 11 show modulation circuits.

Detailed description

Figure 2 shows a circuit according to the invention with two supply voltage sources 1, 4. Implementations of supply voltage sources 1, 4 are known per se and therefore the most important parts are indicated only symbolically. A first supply voltage source 1 comprises a voltage source 2 with supply voltage V1 and filter capacitor 3. A second supply voltage source 4 comprises a voltage source 5 with supply voltage V2, and a filter capacitor 6. The voltages formed by voltage sources 2, 5 are coupled to the outputs of supply voltage sources 1, 4. Filter capacitors 3, 6 are included in a circuit (not shown) to filter out fluctuations in the supply voltage; to that end, they may, for instance, be coupled parallel to voltage sources 2, 5. For each circuit, it holds that the higher the capacitance value of filter capacitors 3, 6, the more fluctuations are filtered out. The voltage sources are indicated very schematically, since there is a large variety of detail circuits, which details are not relevant here.

The output voltages of the two supply voltage sources 1 and 4 are passed to switch 7. Switch 7 is switched in the rhythm of the modulation of the interrogation signal.

Coil 8 connects switch 7 with the transmitter circuit 9. Transmitter circuit 9 comprises an output amplifier for a radiofrequency signal, by means of which an antenna loop 12 is driven. Implementations of transmitter circuits are known per se, and therefore elements from the transmitter circuit are designated symbolically. Resistance 10 indicates the load which the transmitter circuit forms for the supply voltage. Capacitor 11 represents one or mor decoupling capacitors, which serve to close the high-frequency signal paths within transmitter amplifier circuits, and to prevent high-

frequency signal components from the transmitter circuit from flowing back to the modulator and supply circuits.

The transmitter circuit 9 drives the antenna loop 12. This antenna loop has been tuned with the aid of tuning capacitor 13 to the carrier frequency of the interrogation signal, and constitutes a narrow-band resonant circuit.

If coil 8 is not present and is replaced with a through-connection, capacitor 11 will be parallel either to capacitor 3 in supply voltage source 1, or to capacitor 6 in supply voltage source 4. Since the voltages V1 and V2 are different, the voltage across capacitor 11 will, upon switching of the switch 7, also change in one step. This may be accompanied by a high current peak in the connection between the capacitors 3 or 6 on the one hand and capacitor 11 on the other.
The high current peak will give rise to power dissipation in the loss resistances of switch 7. In addition, the steep voltage step of the supply voltage of the transmitter amplifier 9 will give rise to unduly broad modulation sidebands of the interrogation signal, and hence to electromagnetic interference (EMI).

The task of coil 8 is therefore to limit the current peaks and to provide for a gradual variation of the modulated supply voltage of the transmitter circuit. Coil 8 forms, together with capacity 11 and parallel impedance 10, a resonating low pass filter. The resonant frequency is given by $f = 1/2\pi\sqrt{LC}$, while the damping factor D is given by $D = \sqrt{L/C}/R$. R equals the load resistance 10.

The effect of the magnitude of the damping factor on the signal form is visualized in Figs. 3 and 4.

These figures shows the results of SPICE simulations of the present circuit of Fig. 2. V_{in} is the voltage on the node between switch 7 and coil 8. And V_{out} is the supply voltage of the transmitter across capacitor 11. In these figures, it can be properly seen how, and at what rate, the supply voltage approaches the final value after a step, either from the same direction from which the curve starts (undershoot, D = 2.0 and D = 1.7) or a curve which first shoots beyond the final value and then, by way of one or more oscillations, reaches the final value (overshoot, D = 1.33, D = 1.0, and D = 0.67). Further, it is clear that according as the damping factor is smaller, the time required for getting for the first time into the vicinity of the final value is less.

With the output signal, the transmitter drives an antenna, consisting of a tuned loop 12 which, because of the current in the loop, generates a magnetic field. To be able to generate with a limited signal power a strongest possible magnetic field, the circuit current in the loop must also be as large as possible. This is achieved by giving the tuned antenna loop a highest possible Q factor, for instance of a magnitude of Q = 50.
Such a high Q factor for the antenna loop implies a small bandwidth, and hence a long rise time if the amplitude of the transmitted signal is switched from one level to the other.

Figs. 5 and 6 show the resultant form of the amplitude modulation if the tuned antenna loop is driven with a rectangular modulated transmitted signal.

In Fig. 7, the transmitted signal is modulated in a manner according to the invention. It is clear to see that the resultant amplitude modulation has a more rectangular shape, while the inclined flanks and the rounded parts provide for a limit d RF bandwidth. In this simulation, the Q factor of the antenna loop is 27, the damping factor of the modulator circuit is 0.67, the

self-induction of coil 8 is 10 μH, the capacitance of capacitance 11 is 33 nF.

Figs. 8 and 9 show the same as Figs. 6 and 7, respectively, but now for a Q factor of the antenna loop of 50, a damping factor of the modulator circuit of 0.32, and a capacitance of capacitance 11 of 60 nF. These examples show that the manner of modulation according to the invention has a positive side-effect, viz. the possibility of compensating the inertia of a narrowband antenna loop by means of the subcritically damped low pass filter in the modulator circuit.

Accordingly, it may be of interest to make the damping of the low pass filter settable, so that the compensation is such that the resulting modulation is optimal. In the circuit of Fig. 2, damping is determined by the DC load resistance 9, which represents the load by the transmitter amplifier. This resistance cannot be made settable. However, by connecting a settable resistance 14 in parallel, this *can* be realized, see Fig. 10. To prevent this damping resistance from forming a short-circuit for the direct current, capacitor 15 has been connected in series. The capacity of capacitor 15 is much greater than that of capacity 11.

The circuit of Fig. 10 functions satisfactorily for a modulation depth up to 20%. With greater modulation depths, the great capacity of capacitor 13 may cause deformation of the modulation pulses.
A solution to that problem is to arrange the extra damping in the form of a series resistance 16, as represented in Fig. 11. To prevent direct current losses in series resistance 16, it can be bridged with coil 17, in which case the self-induction of coil 17 must be much greater than that of coil 8.

Summarizing, there is provided a radiofrequency identification interrogation unit in which the interrogation signal is amplitude modulated

by switching, with the aid of an electronic switch, the supply for the output amplifier in the transmitter circuit between two well-filtered voltage sources, whose voltage values have been pre-set.

In one embodiment, in the connection between the electronic switch and the output amplifier, a coil can be included having such a self-induction that this coil, together with *inter alia* parallel capacitors present in the output amplifier, forms a low pass filter.

Further, parallel to the output amplifier, or in series with it, a settable resistance can be connected, such that the damping factor of the low pass filter can be set such that in combination with the Q factor of the resonating antenna loop the radiofrequency current through the antenna loop is modulated in an optimum form.